

Human Exploration and Operations Committee Status

Committee Chair - Ken Bowersox
December 10, 2018





- Mr. Bowersox, Ken, *Chair*
- Ms. Budden, Nancy Ann
- Ms. Caserta Gardner, Ruth G.
- Dr. Chiao, Leroy
- Dr. Condon, Stephen "Pat"
- Mr. Holloway, Tom
- Mr. Lon Levin
- Dr. Longenecker, David E.
- Mr. Lopez-Alegria, Michael
- Mr. McDaniel, Mark
- Mr. Sieck, Robert
- Mr. Voss, James



NAC HEO Committee Meeting

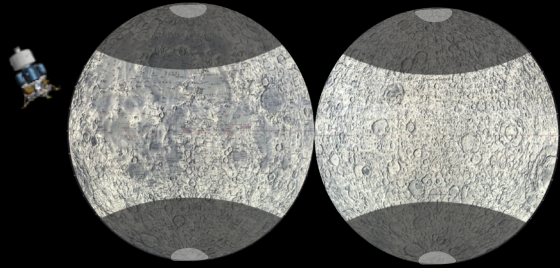
Thursday, December 6, 2018

- Human Exploration & Operations Status
- Commercial Crew Program Status
- Exploration Systems Status
- International Space Station Status
- Discussion, Findings, Recommendations

Friday, December 7, 2018

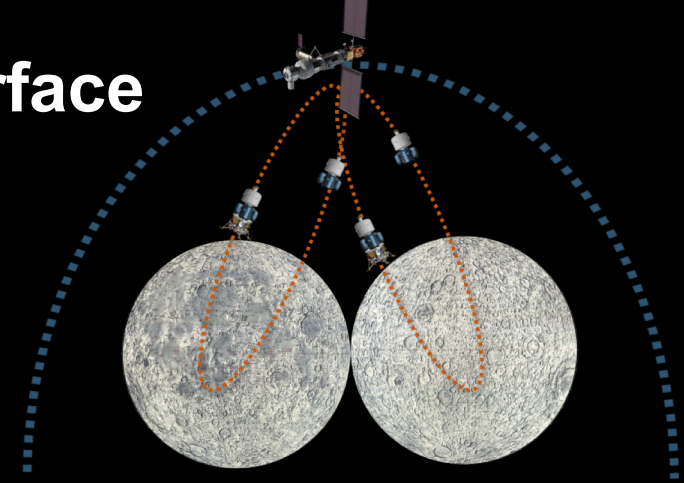
- Advanced Exploration Systems Status – Cislunar Plans
- Power Propulsion Element Status
- Discussion, Findings, Recommendations

Two Approaches for Accessing the Lunar Surface



Lunar Surface Direct Apollo-style

- Lacks reusability
- Does not build or test infrastructure necessary for Mars missions
- Delta-v (0-6 %) more efficient for one- and two-way transfers
- Limited opportunities for commercial launch vehicles
- Limited opportunities for international partnerships
- Some vehicle redesign may be required for vehicles under manufacture
- Science and utilization limited by short mission duration
- Limited ability to test and develop Mars systems and capabilities
- Human cis-lunar presence only during surface missions



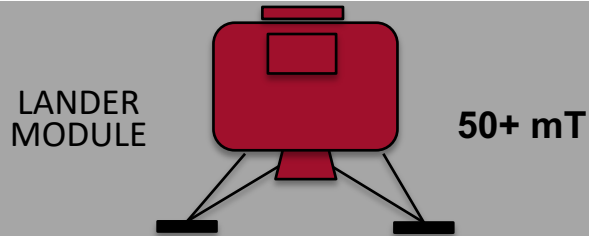
Lunar Surface Through Gateway

- Enables reusable lunar systems
- Enables long-term multiple mission capability (in-space, robotic and human missions across the lunar surface)
- Establishes initial refueling capabilities necessary for Mars
- Lunar vehicle checkout and maintenance at Gateway
- Increased opportunity for international and commercial partnerships reduces political risk
- Longer duration surface missions
- In-space platform for long-duration science
- Deep space testing of Mars-forward systems
- Establishes deep space infrastructure
- Interoperability standards-open architecture
- Lower long-term costs for Mars campaign

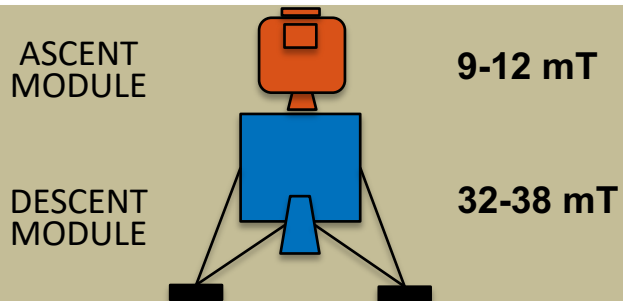
Key Takeaways from Initial Internal Architecture Approach Studies



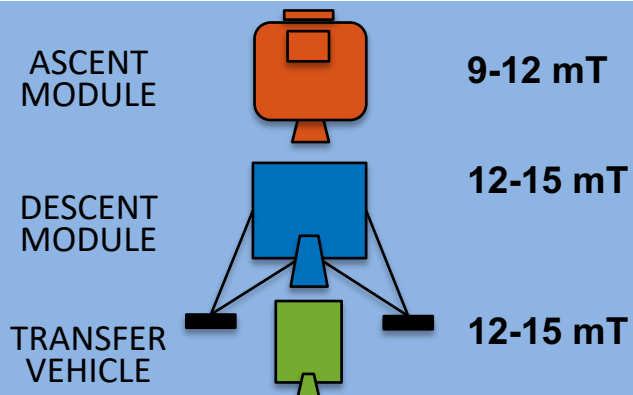
To deliver humans to the Moon, several lander vehicle options were assessed



- **Single-stage human lander**
 - Does not fit on any launch vehicle, including SLS Block 1B Cargo



- **Two-stage options**
 - Ascent Module fits on commercial launch vehicles expected to be available
 - Descent Module does not fit on commercial launch vehicles



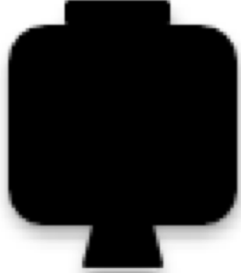
- **Three-stage options**
 - Fits on commercial launch vehicles expected to be available
 - Single elements potentially can be co-manifested payload on SLS
 - Allows increased partnering opportunities

Three Stage Lunar Architecture (Planning/Notional)

Approach driven by available launch vehicles and physics



Ascent Element



- Based at Gateway
- Reusable & Refuellable
- Carries a crew of 4

Approx. Delta-v
2,850 m/s

Target Wet Mass
9 mT to 12 mT

Descent Element

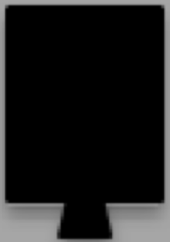


- Performs descent propulsion
- Serves as a cargo lander

Approx. Delta-v
2,000 m/s

Target Wet Mass
15 mT to 16 mT

Transfer Vehicle



- Transfers ascent, descent elements (if applicable) from Gateway orbit to lower orbit for landing
- Potential for reusability
- Could be provided as a commercial service

Approx. Delta-v
850 m/s

Target Wet Mass
12 mT to 15 mT

Other Benefits

Phased Development

- Spreads costs evenly, achieving capabilities for landing science and exploration lunar payloads in support of future crewed missions.
- Human rating requirements are minimal on the upfront developments, as the ascent element with its full abort capability at any crewed mission phase addresses many of the human rating requirements.

Partnering Opportunities

- Smaller element, enable easier point of entry now and in the future for both commercial and international partners, as long as interoperability standards are established.
- Industry partners can move ahead faster with the capabilities they want to build, while NASA builds and sustains unique competencies related to deep space human systems on the ascent element.

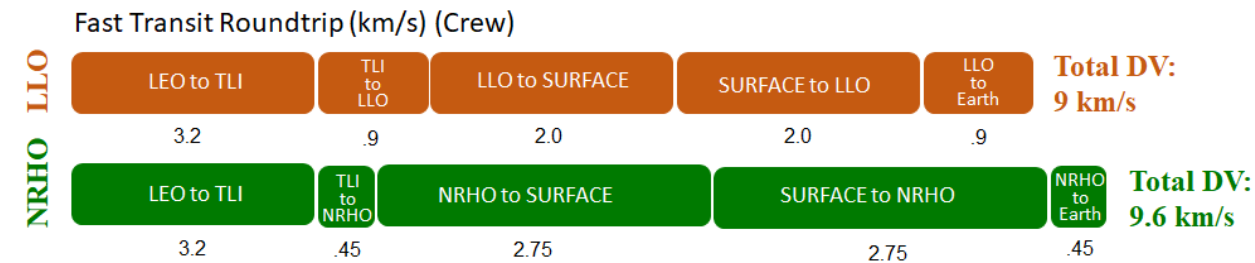
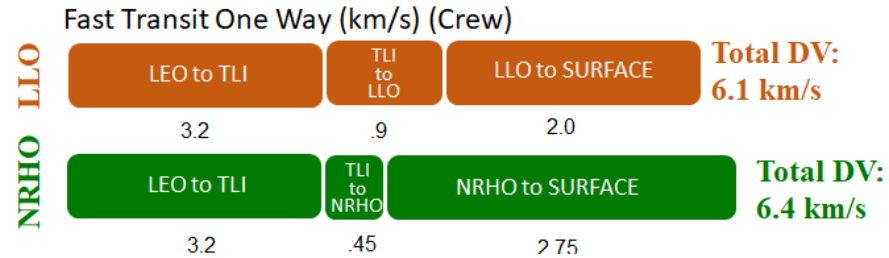
Multi-use Systems

- Elements (or their copies) can be applied to other missions to increase payloads or reduce transportation times (deep space rendezvous with tug for outerplanet missions, satellite maneuvering in GEO vicinity, etc.)
- Possible alternate crewed cislunar missions include NEO rendezvous, L4/L5 tour to observe small objects, or L1/L2 missions to deploy or service remote sensing systems.
- The lunar elements may be partially or fully applicable to aspects of future Mars missions (common ascent systems, etc.)

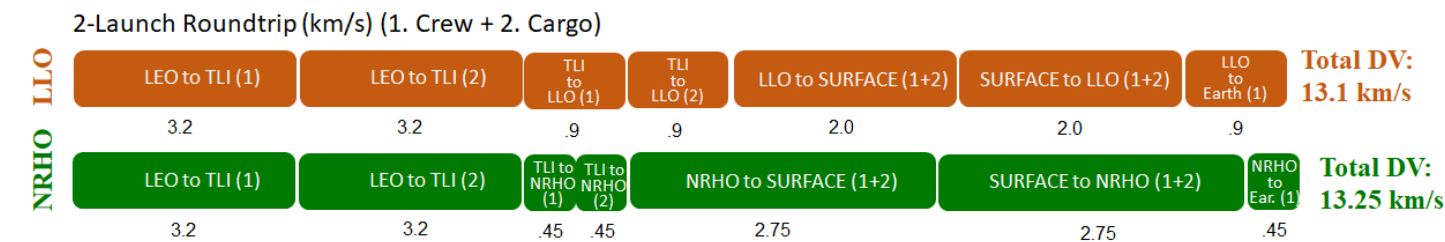


A review of Delta-v of Using Gateway vs. Direct to Moon

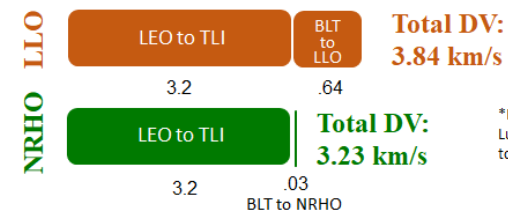
- Fast one way transits to the surface incur about .3 km/s penalty to go through Gateway as opposed to LLO (4.9% of total).
- Round trip transits where everything is delivered fast on a single launch incur about .6 km/s penalty (6.7% of total).



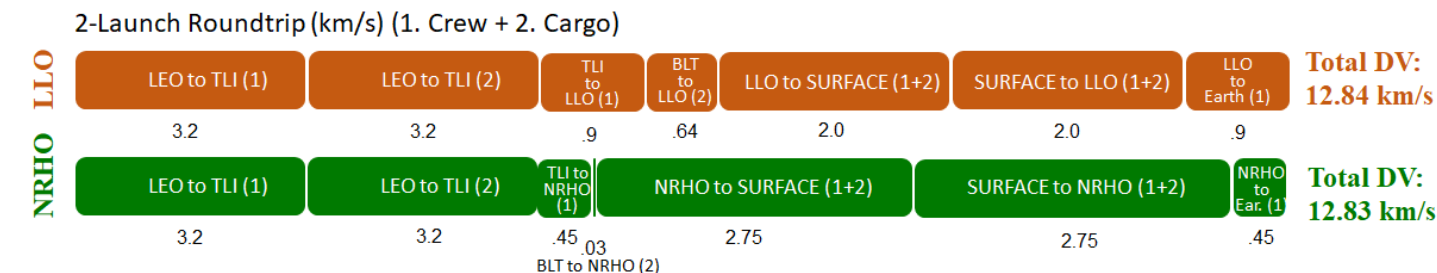
- Round trip fast transits for 2 launches incur only a .15 km/s penalty (1.1% of total).
- Round trip transits for 2 launches where cargo is delivered on ballistic lunar transfer incurs 0 km/s penalty (0% of total).



Slow Transit One Way to Orbit (km/s) (Cargo)



*BLT – Ballistic Lunar Transfer (3 to 4 months)



Why Gateway?



- We've already been to the lunar surface – why not do something more challenging, which will develop capability to go beyond the moon.
- Gateway is for Mars exploration like Gemini was for Apollo – a program to develop new capabilities that will be required to go further into our solar system, and to develop the partnership that was built on ISS.
- The cislunar orbiting platform (Gateway) isn't just about going to the lunar surface, or going to Mars, it's about both, and about going beyond.
- Gateway makes it possible to use of all of the capabilities available in the United States and international partner countries to further human exploration – Orion, SLS, Commercial Launchers, International Launchers, International transport vehicles – and future elements provided by international and commercial partners.
- Gateway allows different elements to be built and operated by different partners, providing multiple options, and minimizing chances that any one partner will be in the critical path.
- Gateway is not ISS around the moon. Gateway is intended to be procured a different way with much less cost – more like commercial cargo than either commercial crew or Orion.

Proposed NAC Finding on the Gateway



- After consideration of switching to a program that goes more directly to the lunar surface, the consensus of the HEO committee members is that NASA should continue moving forward with its sustainable approach to explore cislunar space, including the lunar surface using the Gateway.
- The NAC supports NASA's plans for a lunar orbiting platform that will enable international and commercial partnerships, reusability of hardware to transport crews to and from the lunar surface, reduce risk for lunar exploration crews by providing a safe haven, improve communications with spacecraft on the lunar surface, and provide valuable opportunities for scientific investigations, while expanding the knowledge base in the area of deep space maneuvering and solar electric propulsion required for travel to Mars.



- The Council acknowledges and applauds the direction NASA has taken toward a complementary approach to exploration that facilitates a balance between exploration and scientific discovery. The approach includes work in LEO, cislunar space (currently envisioned as the Gateway), lunar surface exploration, and deep space exploration. NASA's plans have the potential to support both Human Exploration and Operations Mission Directorate (HEOMD) and Science Mission Directorate (SMD) objectives and goals, while meeting the intent of Space Policy Directive-1 (SPD-1) for a return to the Moon. This concept feature a role for international and commercial partners, reusability, sustainability, reconfigurable components, and builds toward the ultimate national vision for deep space exploration and science, including a crewed mission to Mars.
- From August 2018 NAC meeting.

Proposed NAC Finding on the Gateway



Finding: Space Policy Directive 1 tasks NASA to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. It also tasks NASA with returning to the moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.

To meet the exploration and science requirements which flow down from SPD-1, NASA has formulated a plan based on establishment of a lunar orbiting platform that will enable international and commercial partnerships, reusability of hardware to transport crews to and from the lunar surface, allow critical access to the lunar polar regions, reduce risk for lunar exploration crews by providing a safe haven, improve communications with spacecraft on the lunar surface, and provide valuable opportunities for scientific investigations, while expanding the knowledge base in the area of deep space maneuvering and solar electric propulsion required for travel to Mars.

The NAC strongly endorses NASA's plan for achieving the goals set forth in SPD 1.

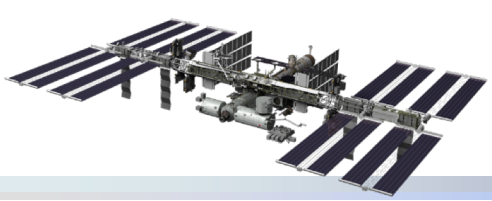
Proposed NAC Recommendation on Support for Program Managers



Recommendation: The NAC recommends that while working to implement improvements that have been recommended for programs like the James Webb Space Telescope and the Space Launch System, NASA should also take positive action to ensure that the policies which are within the agency's control, provide needed flexibility for program managers to enhance the agency's ability to continue its innovative and inspiring efforts in the exploration of Space. The first step in this process should be to solicit inputs from program managers on factors that would help them better meet all their obligations.

Major Reasons for the Recommendation: The NAC applauds NASA's work, consistent with the National Space Policy Directives in bringing back to earth new knowledge and opportunities through innovative and inspirational space programs and technical advances, which were based on a culture of discovery, risk acceptance and learning. NASA's rich history of managing large projects includes huge mission successes like the Apollo program, Viking, Voyager, and the Hubble Space Telescope. The managers of these successful programs were given enough flexibility and resources to accomplish tasks that had never been done before. The council observes that the large programs of today are facing a change in the external and internal environment, which is creating a change in program and project management. The culture being created is focused on compliance and failure prevention at the expense of innovation and inspiration. Programs and projects are learning to pass audits and failing to deliver programs. While oversight of programs is important, NASA needs to be able manage. And the more challenging the project, the more it needs the flexibility and resources to manage well.

Consequences of No Action on the Recommendation: Additional constraints will make it more and more difficult for program managers to address program challenges, and could result in attitudes toward risk which discourage innovation.



Increment 57/58 Overview: Crew



NASA/S.Aunon-Chancellor - Roscosmos/S. Prokopyev – ESA.A. Gerst

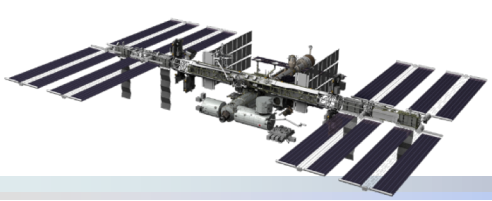
55S Dock 6/8/18
55S Undock 12/20/18



NASA/Anne McClain - Roscosmos/Oleg Kononenko - CSA/David Saint-Jacques

57S Dock 12/03/18
57S Undock 06/17/19





Soyuz Anomalies

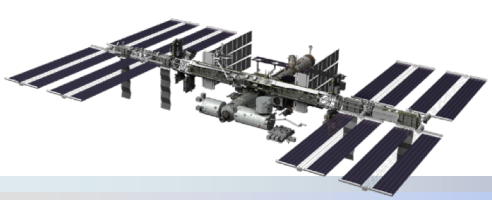
Soyuz 55S Hole (Aug 29/30, 2018)

- Flight Control Team in MCC-H noticed drop in cabin air pressure. Crew isolated the leak to a ~2mm hole in the orbital module of Soyuz 55S.
- After discussion with ground, crew repaired the hole using an onboard patch kit. Following re-pressurization, onboard pressure has been stable since completion of the repair.
- Roscosmos commission established to investigate the cause of the hole. Spacewalk planned in December to gather more data.

Soyuz 56S Launch Abort (Oct. 11, 2018)

- Shortly after launch, an anomaly with a first-stage booster triggered events which initiated a launch abort resulting in a ballistic landing of the spacecraft.
- Launch Abort System worked as designed, crew (NASA/Hague, Roscosmos/Ovchinin) returned safely.
- Roscosmos commission performed thorough investigation and determined cause to be deformation of contact sensor.
- Flight Readiness Review on 11/15 to evaluate next crewed Soyuz launch planned for 12/3.

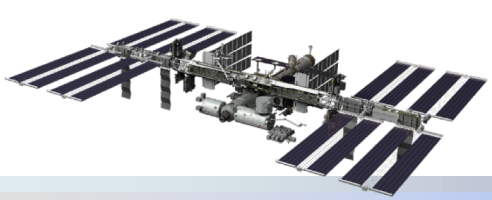




Flight Plan – Increment 57

- 10/04/18 – Soyuz 54S Undock/Landing (NASA/Feustel, NASA/Arnold, Roscosmos/Artemyev)
- 10/11/18 – Soyuz 56S Launch Abort (NASA/Hague, Roscosmos/Ovchinin)
- 11/07/18 – H-II Transfer Vehicle 7 (HTV-7) Unberth and Release
- 11/17/18 – Northrop Grumman CRS-10 (NG-10) Launch
- 11/16/18 – Progress 71P Launch
- 11/18/18 – Progress 71P Docking
- 11/19/18 – NG-10 Capture/Berth
- 12/03/18 – Soyuz 57S Launch/Docking (NASA/McClain, CSA/Saint-Jacques, Roscosmos/Kononenko)
- 12/04/18 – SpaceX CRS-16 (SpX-16) Launch
- 12/06/18 – SpX-16 Capture/Berth
- 12/11/18 – RS EVA #45A (Soyuz 55S Hole Inspection)
- 12/20/18 – Soyuz 55S Undock (NASA/Aunon-Chancellor, Roscosmos/Prokopenko, and ESA/Gerst)
- Two upcoming US EVAs (P4 Battery R&R) – dates under evaluation.





Increments 57 & 58

► Increment 57: 77days

- Stage 57-3: 53S undock to 55S dock: 60 days
- Stage 56-6: 55S dock to 54S undock: 17 days
- EVAs
 - RS EVA (12/11) Soyuz Inspection
 - US EVA (TBD) P4 Battery R&R – 4A
 - US EVA (TBD) P4 Battery R&R – 2A

◦ Visiting vehicles:

- HTV7 (Unberth 11/7)
- Progress 71P (Launch 11/16, Dock 11/18)
- NG-10 (Launch 11/17, Berth 11/19)
- SpX-16 (Launch NET 12/4, Berth 12/6)

Science/Utilization:

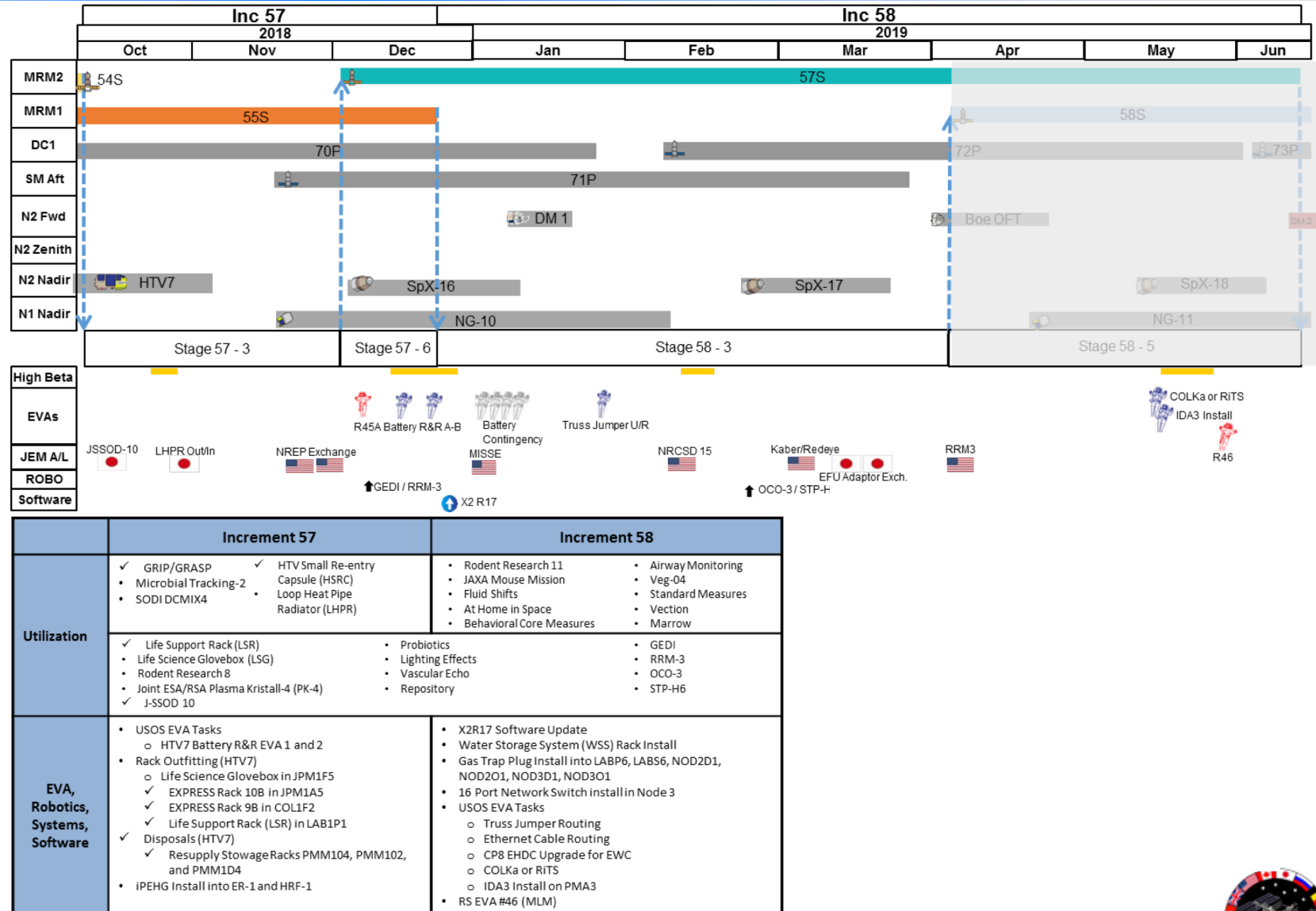
- Augmented Utilization Hours
- RR11

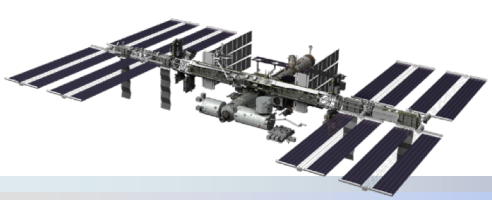
◦ Maintenance/Outfitting:

- LSG Installation
- EXPRESS Rack 108 and 98 Installation
- X2R17 Software Update
- Wate Storage System (WSS) Installation

◦ Other:

- GEDI and RRM3 Installation





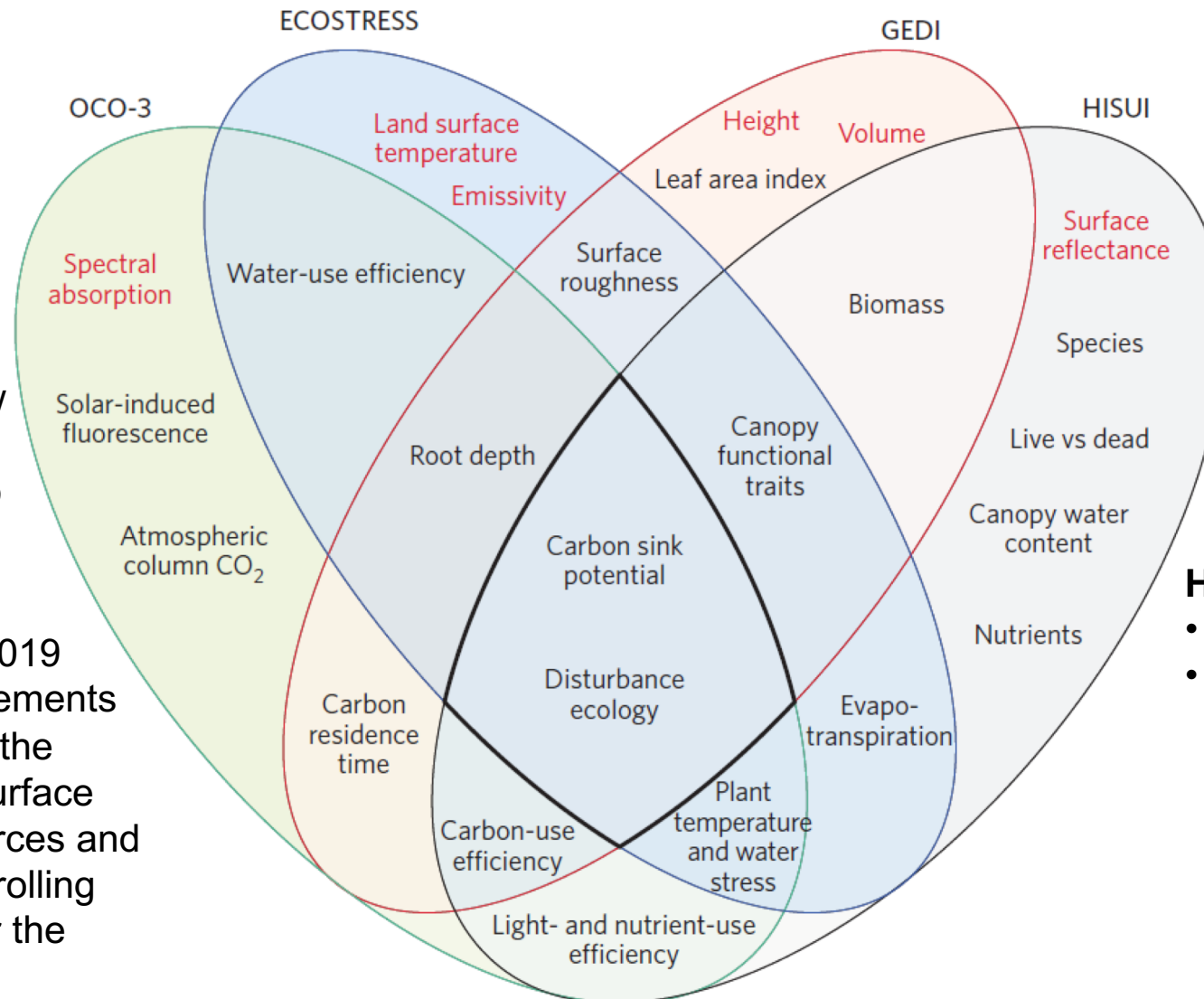
Earth Observation Instruments Synergy

ECOSTRESS

- Launched July 2018
- Multispectral thermal infrared sensor to measure the brightness temperature of plants, and use that information to better understand how much water plants need and how they respond to stress

OCO-3

- Launching in Feb 2019
- Will collect measurements needed to improve the understanding of surface carbon dioxide sources and the processes controlling their variability over the seasonal cycle



GEDI

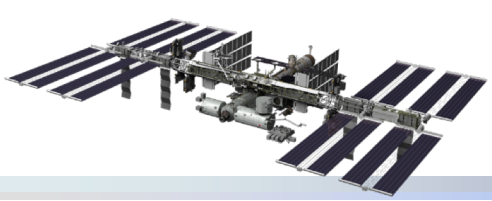
- Launching in Dec 2018
- Active sensor system to characterize the effects of changing climate and land use on ecosystem structure and dynamics to enable improved quantification and understanding of the Earth's carbon cycle and biodiversity.

HISUI

- Launching Jan 2020
- Will obtain calibration and data to start a full-scale practical application development for hyperspectral remote sensing through the manufacturing and in-flight performance verification

Photo Credit: ISS observations offer insights into plant function PUBLISHED: 22 JUNE 2017 |
VOLUME: 1 | ARTICLE NUMBER: 0194 NATURE ECOLOGY & EVOLUTION 1, 0194 (2017)





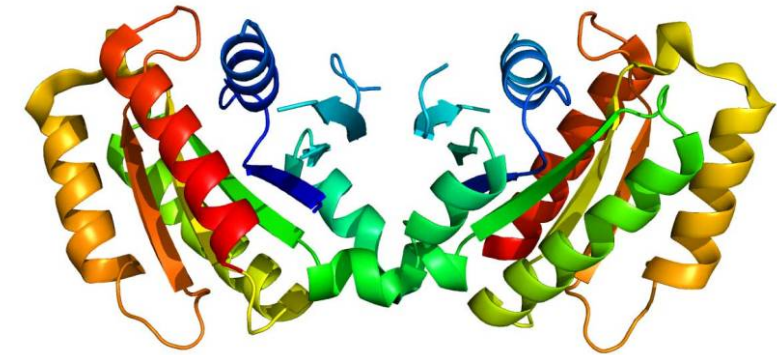
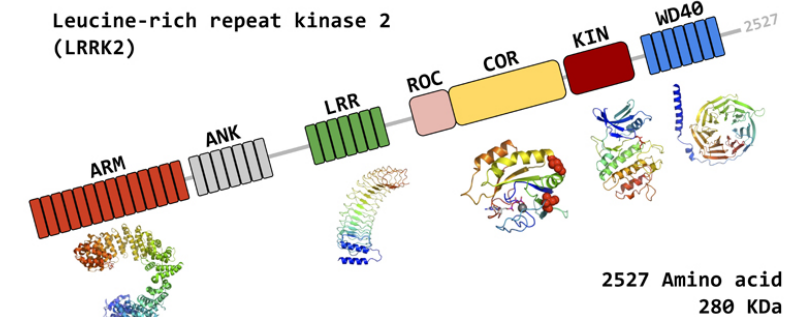
CASIS Protein Crystal Growth (PCG) 16: Crystallization of LRRK2 Under Microgravity Conditions –2

Continuing pursuit of the atomic structure of the leading Parkinson's Disease protein

Principal Investigator: Michael J Fox Foundation, Goethe University Frankfurt, University of California – San Diego

Sponsor: ISS National Lab

- Determining the structure of the Leucine Rich Repeat Kinase 2 (LRRK2) protein is the leading approach for developing drugs that would mitigate Parkinson's Disease
 - If the structure is known, a drug can be developed to attach to the protein to render it un-functional
- Many attempts to grow the LRRK-2 protein on Earth have not been successful due to sedimentation and convection, making the crystal too small to study
- Microgravity environment allows crystal to grow larger in structure to make it easier to see and evaluate
- Second attempt to grow crystal on ISS, (first was unsuccessful) but is utilizing the CASIS PCG-13 experiment by Eli Lilly to increase chances of success
 - Experiment assists the astronauts in observing imperfections while growing crystals in microgravity and training them to make real time adjustments



Cold Atom Laboratory – a Facility for Quantum Science on ISS

- Microgravity offers the possibility of dramatically reducing the forces needed to confine an ultra-cold sample of atoms
- This allows us to reach a new regime of ultra-low temperatures
- Ultra-cold samples created by CAL can float unconfined for long periods, nearly fixed relative to the apparatus

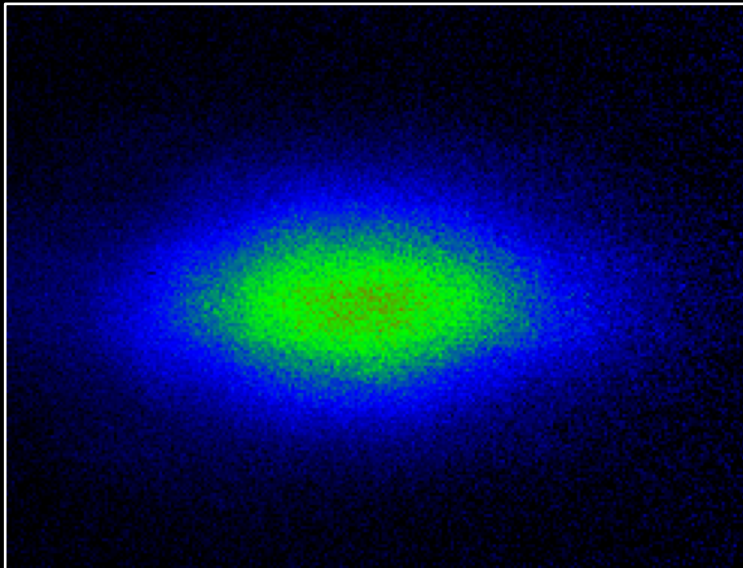
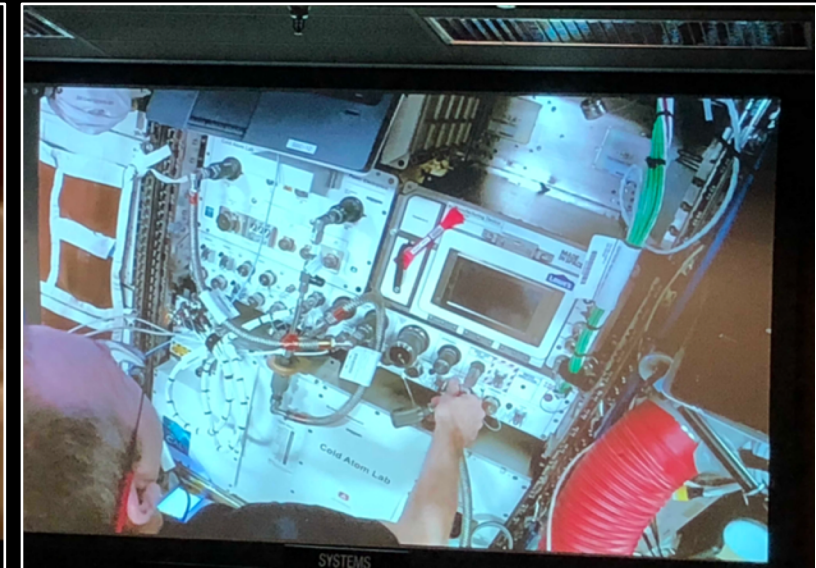


Image of the first cold atoms in orbit

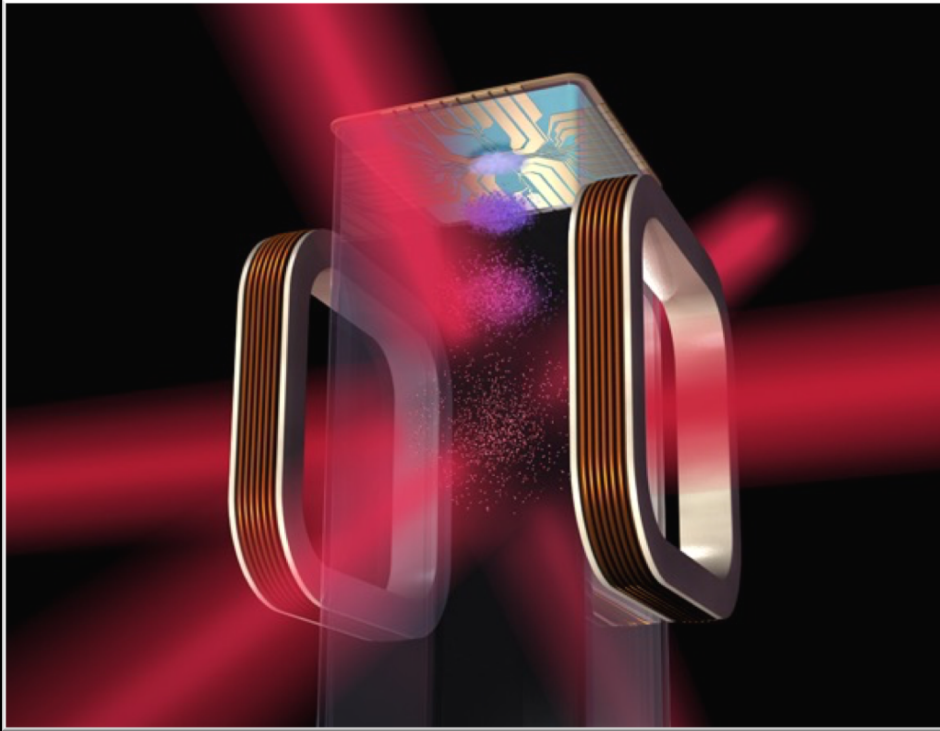


Launch upon Cygnus OA-9



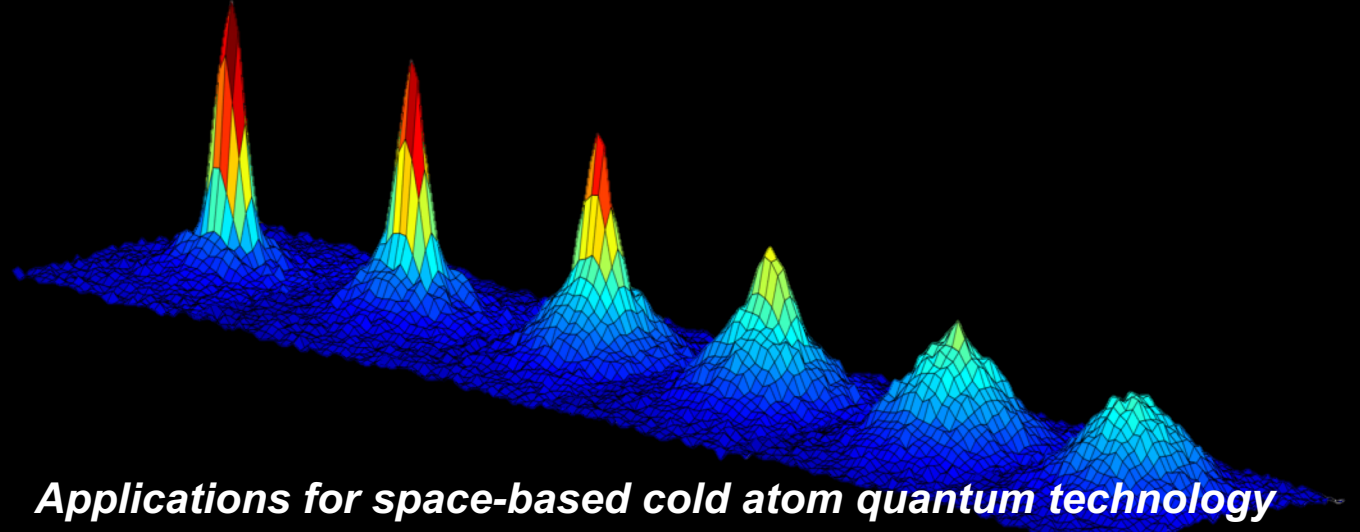
Installation aboard ISS

Cold Atom Research in Space



CAL uses multiple lasers to cool clouds of atoms to temperatures below 1 nanokelvin. Laser cooling works better in space because the atom trap doesn't require energy to hold the atoms up. CAL Co-I William Bill Phillips was awarded the Nobel Prize in Physics in 1997 for his contribution to laser cooling.

When a cloud of Boson atoms is cooled to nanokelvin temperatures, they can form a Bose-Einstein Condensate, a dense cluster of atoms sharing a single quantum state—shown here in red. CAL investigators Eric Cornell and Wolfgang Ketterle were awarded the Nobel Prize in Physics in 2001 for their work on Bose-Einstein condensates.



Applications for space-based cold atom quantum technology

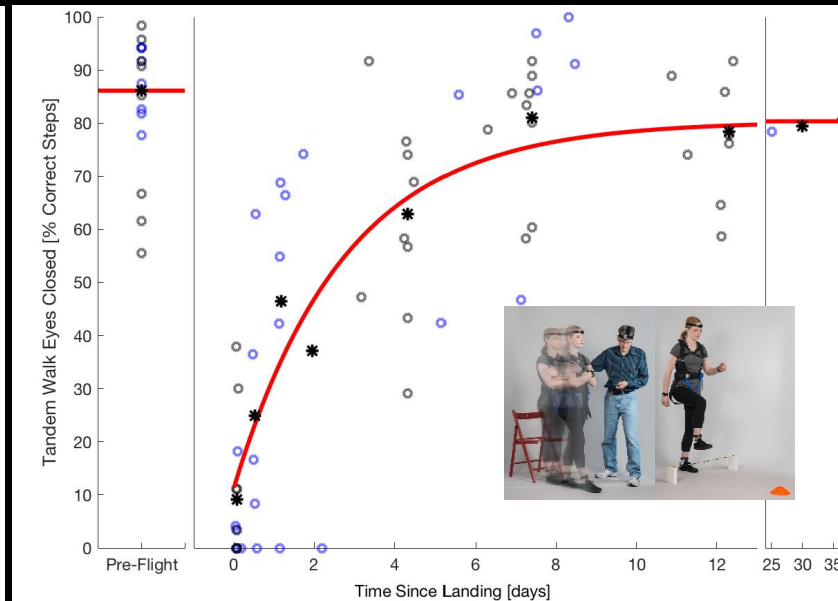
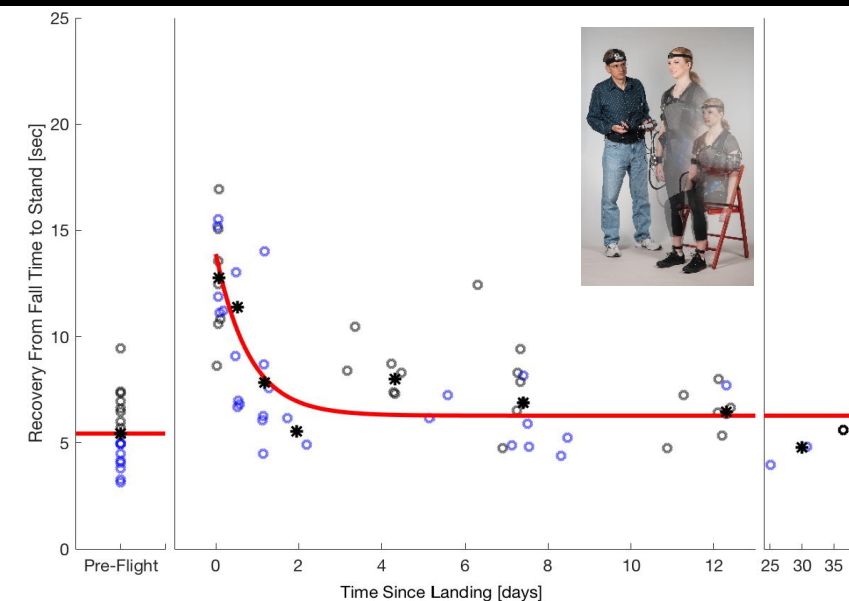
- *Experimental physics on macroscopic quantum matter*
- *Tests of quantum entanglement (Einstein's "spooky action at a distance")*
- *Atom interferometry for gravitational anomaly and dark matter/energy detection*

Crew Performance After Landing

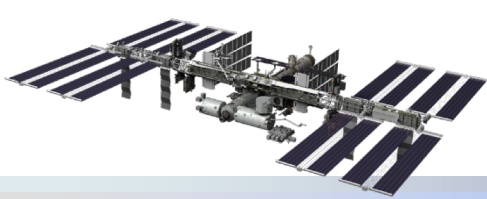
(Field Test)

PIs: MF Reschke (NASA/JSC) & IB Kozlovskaya (RAS/IMBP)

- n=36 returning crewmembers (19 USOS, 17 Rus) from 17 Soyuz landings
- Every returning crewmember exhibits vestibular/cerebellar and sensorimotor decrements
- Every crewmember experiences landing-related motion sickness
- There is considerable variations between crewmembers performance
- Strength is likely not the limiting factor because of current in-flight exercise countermeasures
- **Emergency egress during/after a water landing will present a significant risk to astronaut safety**



Update: Data/videos presented to all relevant operational program managers + new administrator



ISS as a Platform for Demonstration of Advanced Suit Systems

- ▶ The objective of this flight project is to develop a exploration-class EVA suit and perform EVA demonstrations on ISS
 - Will perform demonstration with 1 xEMU and 1 current EMU per EVA sortie
- ▶ The xEMU designed and built is being lead using the NASA team that has been performing EVA technology development for 10+ years
 - NASA will be procuring components and will perform the role of system integrator
 - 1 Qual Unit and 1 Flight Unit will be assembled
- ▶ Major milestones are shown in the table below working towards a flight demonstration at the ISS in 2023
- ▶ xEMU demo will form the basis for the system that will be used at the Gateway and the lunar surface

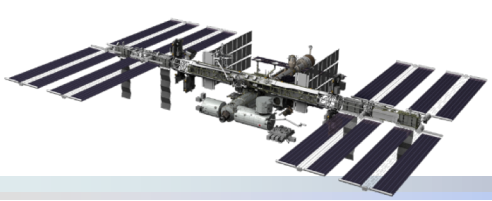


xEMU Demo

FY18	FY19	FY20	FY21	FY22	FY23
SRR (Jan)	PDR		CDR		SAR & Delivery
DVT Build/Assy		DVT Testing	Qual & Flight HW Build		Acceptance Testing
				Qual Testing	

Terms and Definitions: SRR – System Requirements Review, PDR – Preliminary Design Review, CDR – Critical Design Review, DVT – Design Verification Testing, SAR–Systems Acceptance Review





xEMU Demo (Heritage vs. New Hardware)

- ▶ Current EMU components used on xEMU (white items)
 - Lower Arms & Gloves
 - Lower Torso Assembly
 - Legs & Boots
- ▶ Other shared items
 - Lights & Hi-def cameras
 - Tools
 - SAFER
 - Material certs, ex. Polycarbonate for helmet bubbles, TMG, etc

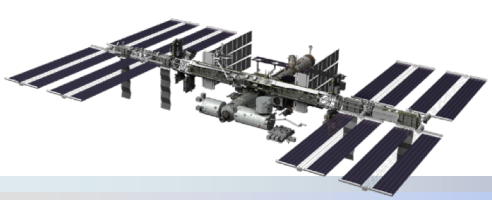


- New XEMU Demo components

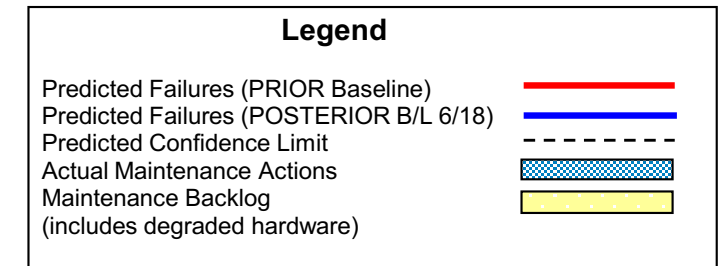
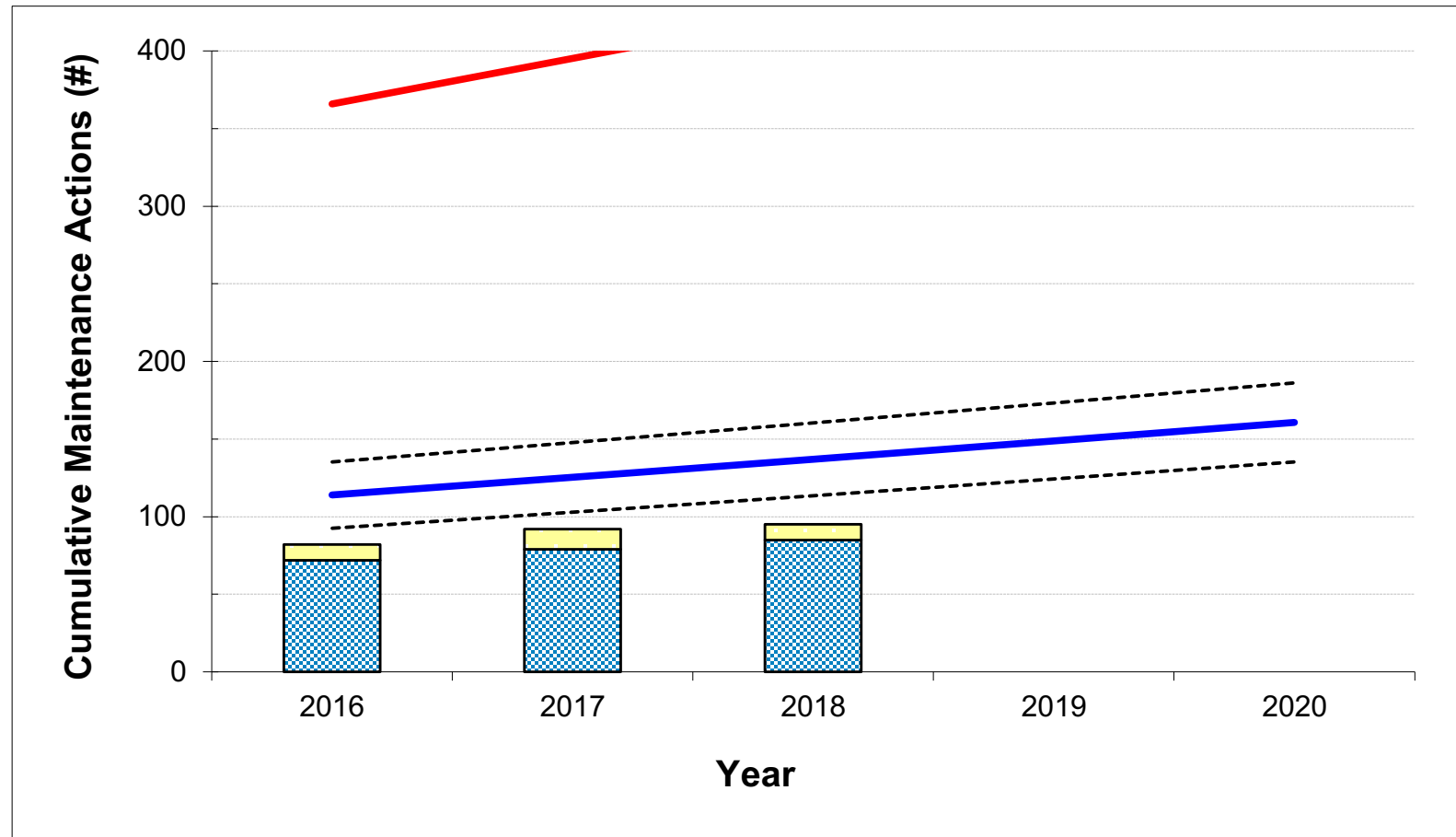
- Portable Life Support System (PLSS)
- Hemi-ellipsoid Helmet & Visors
- Rolling convolute shoulders
- Hard Upper Torso (rear entry) with new control module
- Liquid Cooling & Ventilation Garment
- In-suit comm system

Use of heritage components allows NASA to focus on development of critical Space Suit elements (and diminish ISS logistics / operations integration)



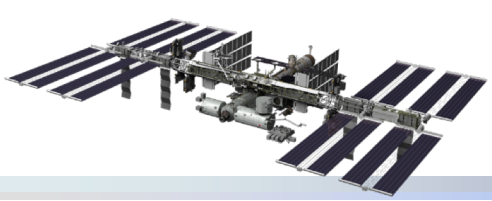


External Corrective Maintenance Trends

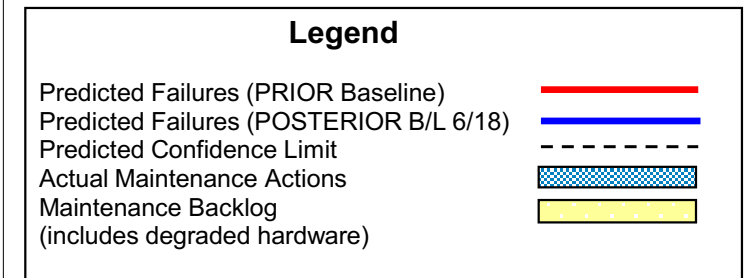
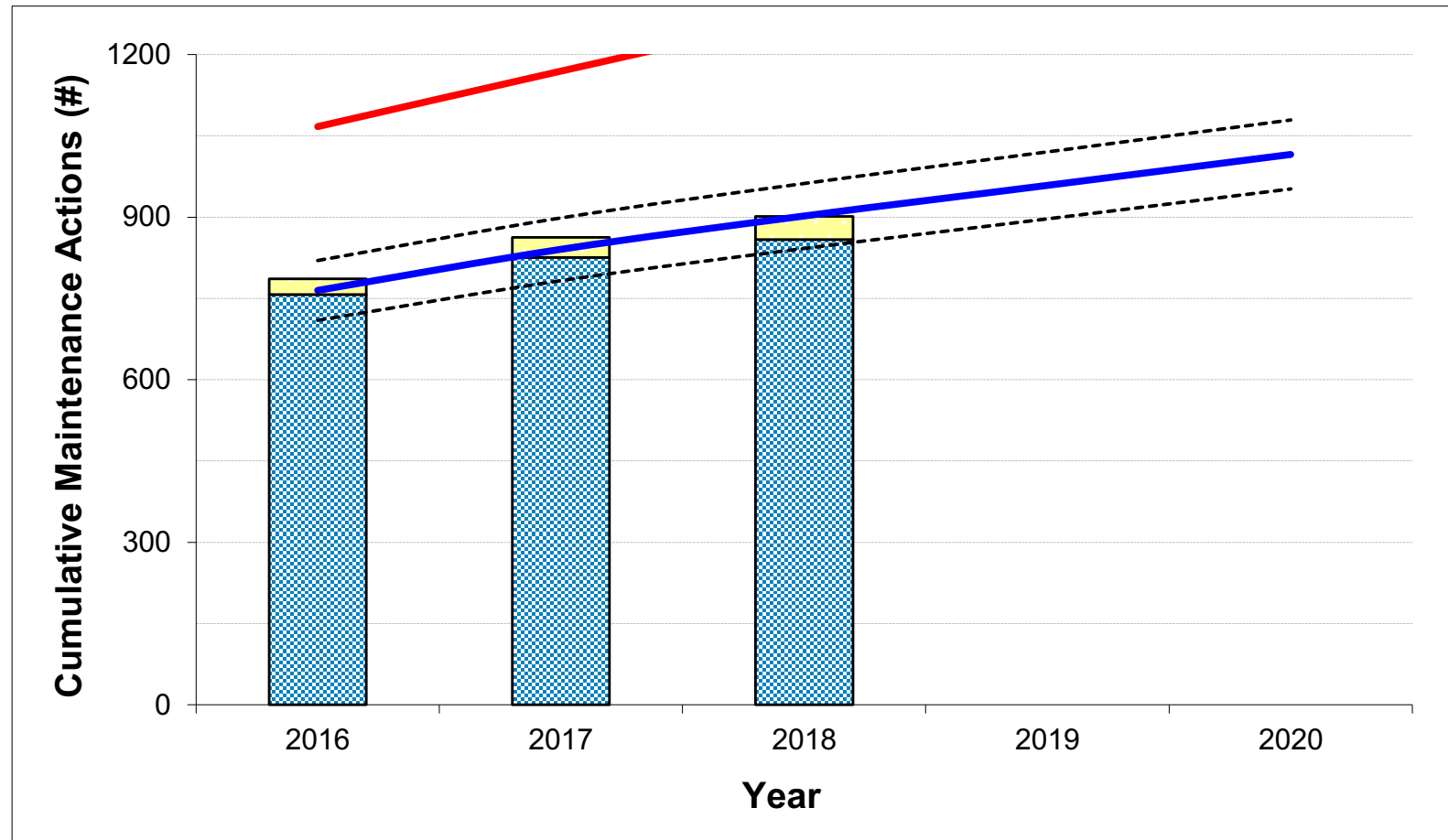


- ▶ Actual Maintenance Actions include Troubleshooting



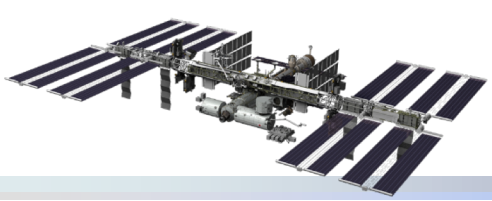


Internal Corrective Maintenance Trends

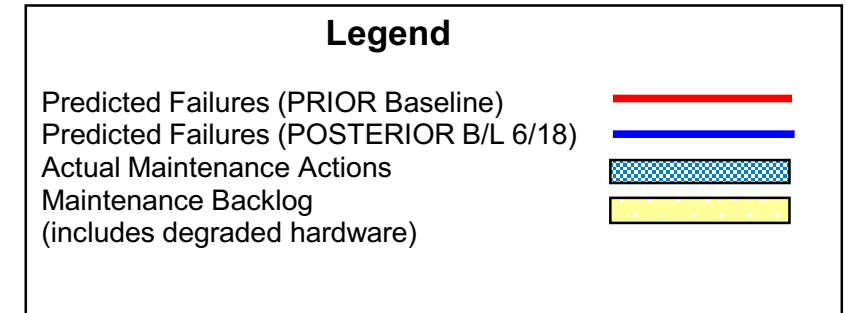
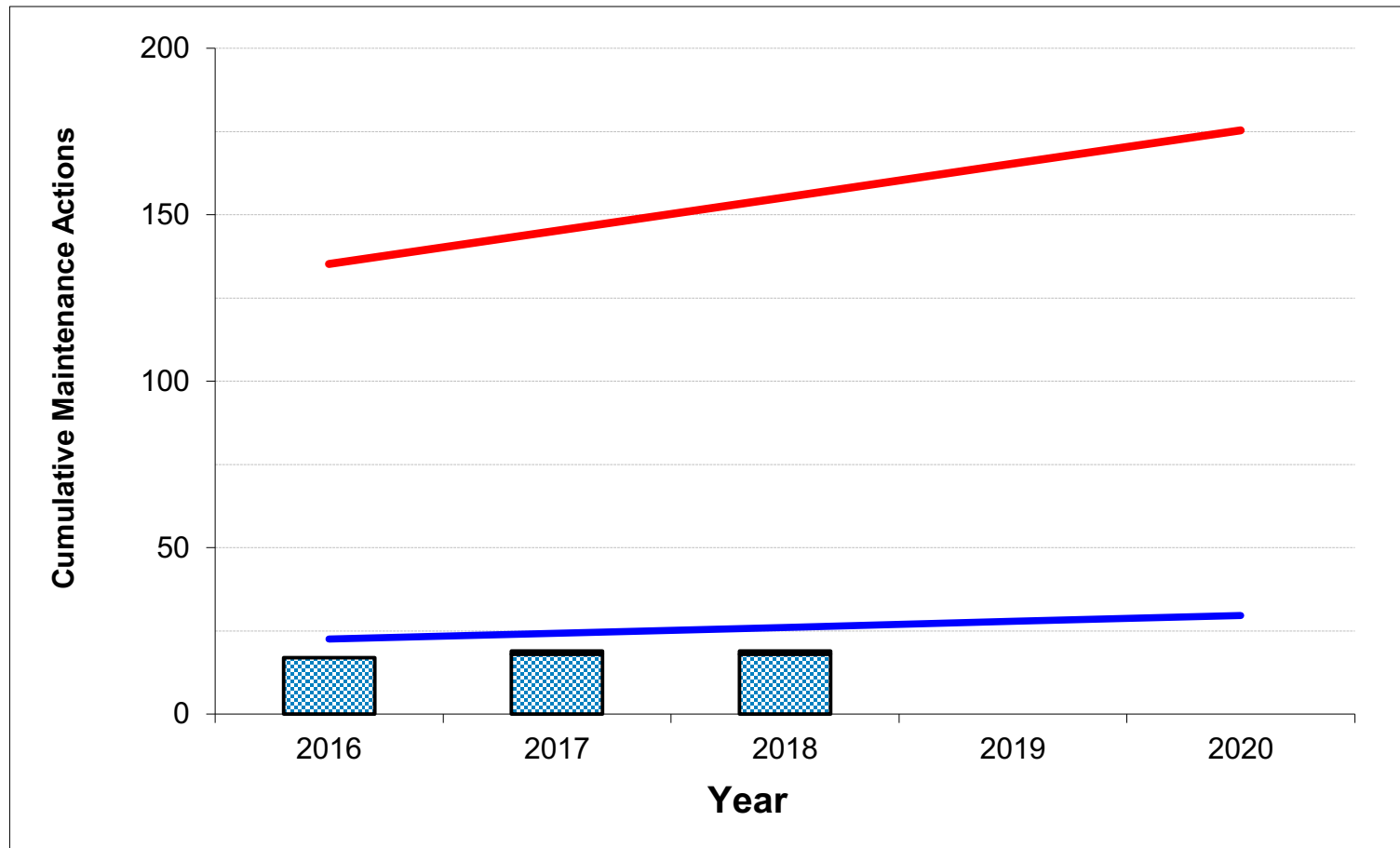


- ▶ Actual Maintenance Actions include Troubleshooting



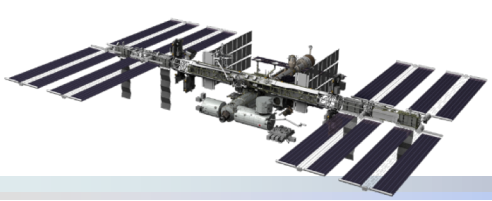


C&DH Corrective Maintenance Trends

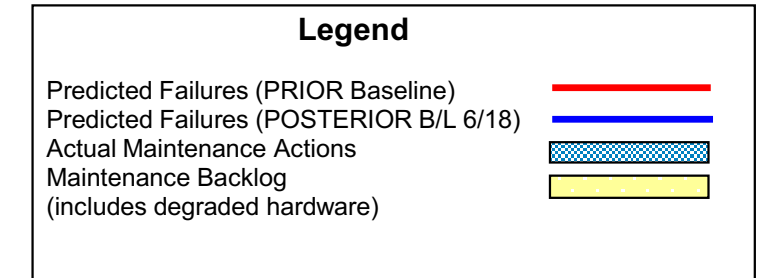
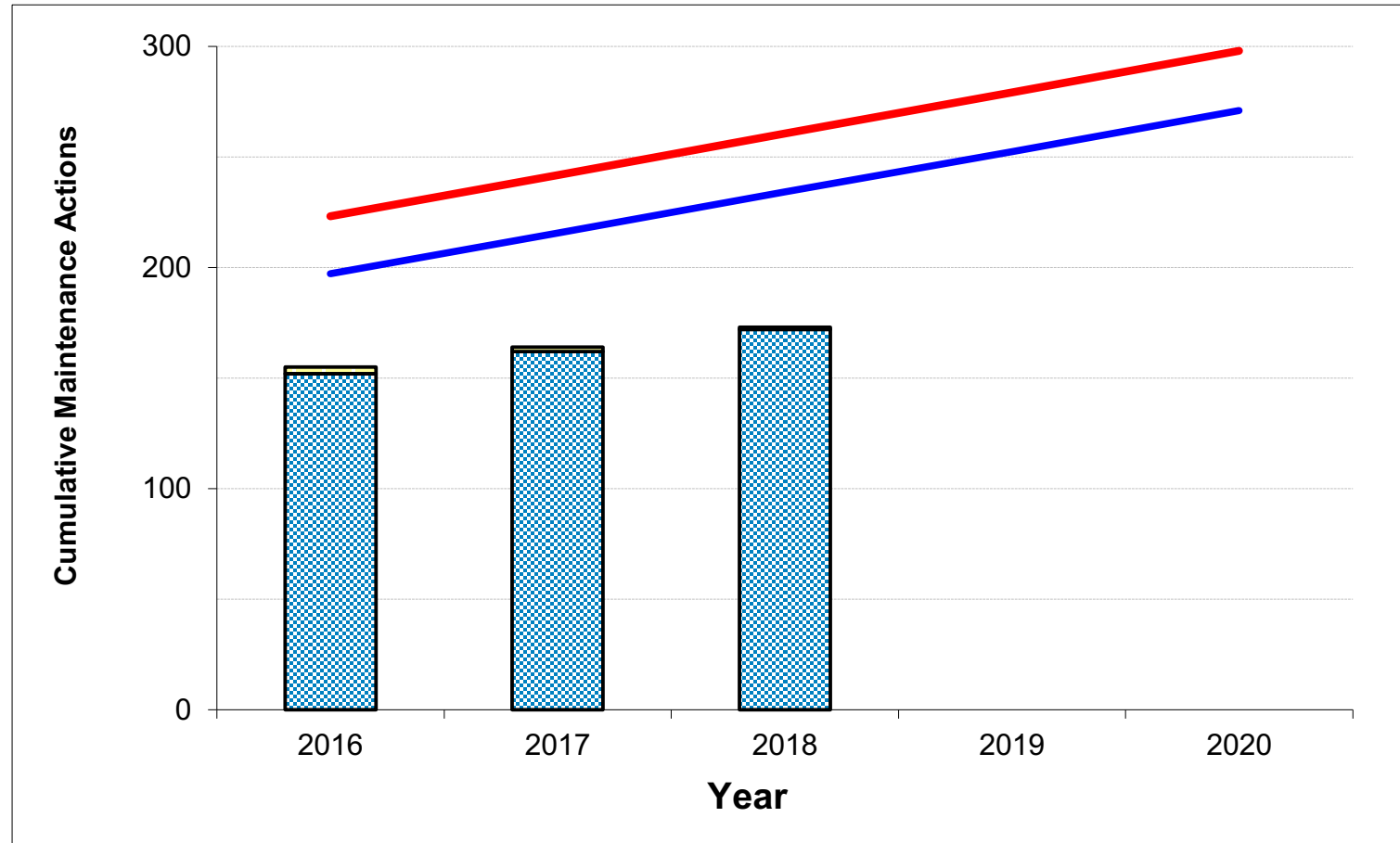


- ▶ All C&DH ORUs have performed better than predicted
 - Multiplexer/Demultiplexer (MDM) ORUs have performed between 3 and 10 times better than predicted
- ▶ Actual Maintenance Actions include Troubleshooting





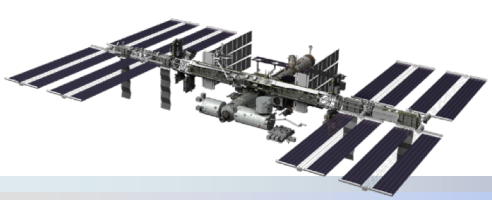
Non Regen-ECLSS Corrective Maintenance Trends



- ▶ Overall Non-Regen ECLSS ORUs have performed better than predicted.
 - Exceptions are:
 - CO2 Removal Dessicant/Absorbent ORU (Predicted MTBF 77,000, Operational 19,000) which is being redesigned as part of Exploration ECLSS CO2 removal upgrades
 - CO2 Removal Air Selector Valves (Predicted 117,000, Operational 29,410). Upgraded DTO valve was installed in Dec 2016 and has been performing well.

Actual Maintenance Actions include Troubleshooting

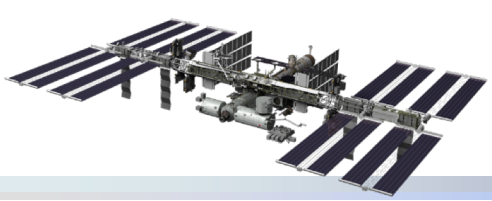




Summary

- ▶ The vehicle continues to perform better than predicted.
- ▶ Bayesian analysis has significantly closed the gap between actual and predicted maintenance demands.
 - NASA has implemented a semi-annual Bayesian update process.
 - Improving the accuracy of maintenance projections.
 - Continuing to refine the correlation of the Logistics & Maintenance predicted corrective maintenance with actual on-orbit experience.
- ▶ As operational experience is established, actual and projected demand will converge.





ISS Transition

- ▶ NASA released a NASA Research Announcement (NRA) to solicit proposals for study activities related to the development of a LEO commercial market where NASA could be one of many customers
 - Released on May 17, 2018
 - Received proposals on June 18, 2018
 - Selected companies announced on August 8, 2018 (contracts are dependent on negotiations)
 - Final study reports delivered to NASA in December 2018



- NAC Finding from July, 2017

Finding: The Council finds that the International Space Station (ISS) is a critical facility for development of systems that will be used for deep space exploration, especially for life support systems. Current projections show approximately two years of run-time on deep space exploration life support systems onboard ISS – in preparation for what may be a three-year crewed mission to Mars in the 2030s. While the official commitment to ISS currently ends in 2024, the Council believes that it is likely that exploration development in low Earth orbit will need to be continued past 2024.

Ideally, the end of government support for the ISS would be determined by clear criteria for its required use, availability of commercial alternatives, and would be a gradual reduction in support rather than a sharp cutoff at a fixed date. Early understanding of ISS availability after 2024 will improve the station's science utilization and improve the likelihood that commercial providers will be able to sustain low Earth orbit operational capability after the government reduces support.



- Engineering analysis has been performed to extend ISS until 2028. Based on the different ages of current ISS elements, it is very likely that some elements of ISS will remain useful well past 2028. Further engineering analysis will be required for extension of any ISS elements past 2028.

HEO Committee Observation:

- NASA has set forth a clear set of principles to guide its ISS transition plan for 2024 and beyond, and submitted a report on ISS transition to congress. The committee looks forward to reviewing the responses from industry to NASA's most recent NASA Research Announcement (NRA) on ISS transition, which are expected in December of 2018.

HEO Committee Concern:

- Shifting priorities may result in the reduction of government funding for the ISS before a viable U.S. commercial follow-on capability is established. This capability is critical to allow NASA continued access to low Earth orbit for research, deep space exploration system testing, and other applications that may arise.

Space Communications and Navigation (SCaN)

Network Services

- Network proficiencies (October 2018):
 - Deep Space Network: 99.3%
 - Near Earth Network: 99.6%
 - Space Network: 99.9%
- Completed reflector lift on the new 34 meter antenna at the Madrid Deep Space Communications Complex (DSS-56)
 - Next Space Technologies for Exploration Partnerships -2 (NextSTEP-2) RFI completed May 2018
 - Broad Agency Announcement released October 2018
 - Proposals due November 2018

Advanced Communication and Navigation Technology

- NASA and ESA jointly recommended that the High Photon Efficiency (HPE) standard be used throughout the Lunar environment and on the Gateway
 - Recommendation was supported by the entire CCSDS Optical Communications Working Group
- Laser Communication Relay Demonstration (LCRD) payload is complete and waiting shipment for integration
- Deep Space Optical Communications (DSOC) passed PDR in October 2018
 - Provide higher data rate links for near-Earth and enable more efficient photon-starved links for deep space
- ILLUMA-T and O2O successfully completed and passed PDR in June 2018
 - ILLUMA-T operations with LCRD in GEO
 - O2O will be a high-rate optical communication link supporting Orion EM-2 crew exploration vehicle



Reflector lift of DSS-56 at the Madrid Deep Space Communications Complex



LCRD packaged and prepped for shipping



Phillip McAlister

Director, Commercial Spaceflight Development
December 2018

National Aeronautics and
Space Administration



COMMERCIAL CREW



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Program Progress

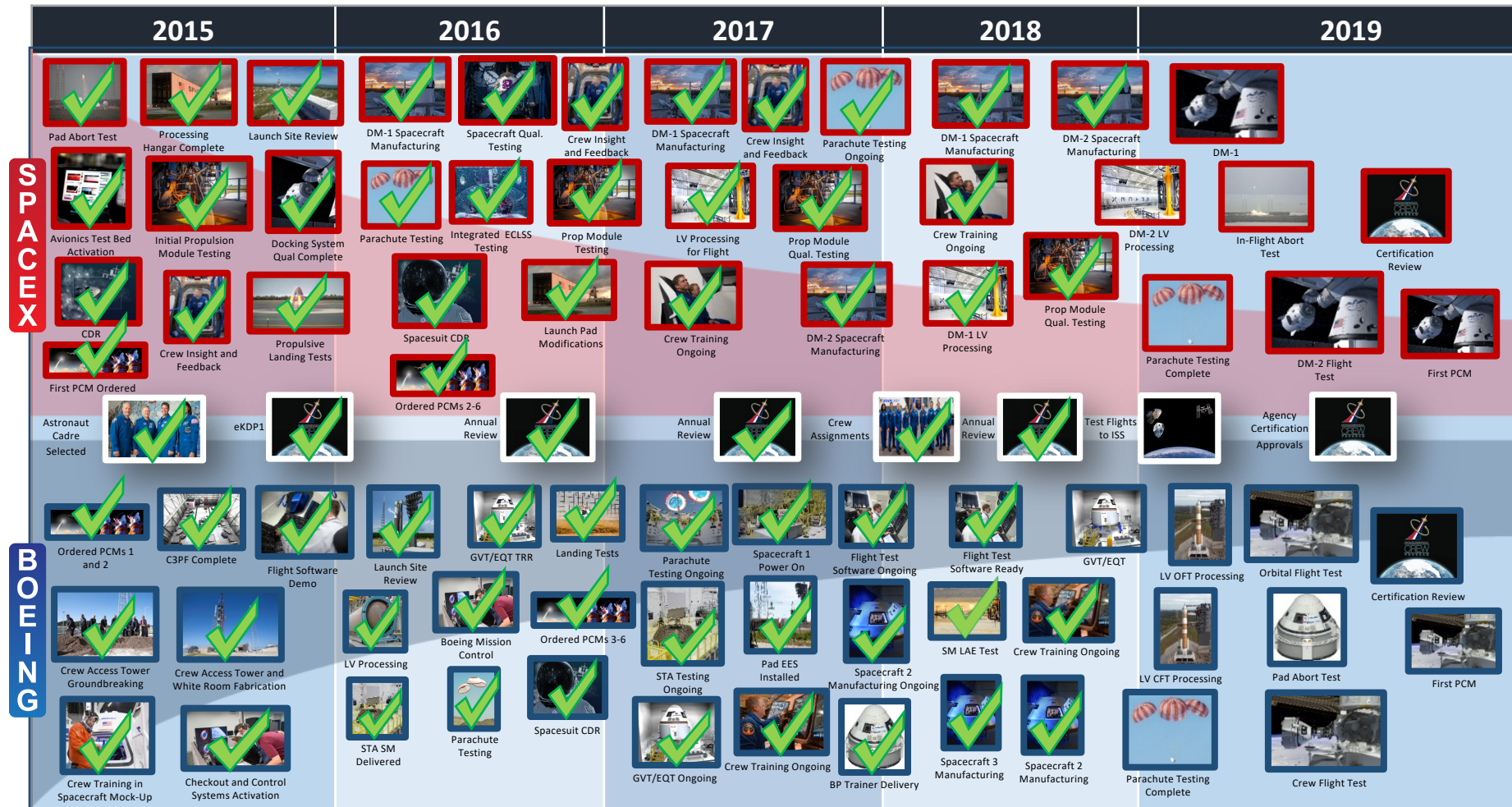


CCP has made significant progress over the last quarter

- **Mission planning and preparations for eight CCP missions are in work**
 - Boeing:
 - March 2019: Orbital Flight Test (uncrewed)
 - August 2019: Crewed Flight Test (with crew)
 - SpaceX:
 - January 7, 2019: Demo Mission 1 (uncrewed)
 - June 2019: Demo Mission 2 (with crew)
- **Space hardware manufacturing, testing and qualification are underway**
- **Continued engagement as the providers perform critical test and verification events**
- **Continue to make progress in the burn down of key certification products with the providers**
 - Progress for each partner is included in provider-specific sections of this briefing



Timeline to the International Space Station



Last Updated
Nov 2018



Space Act Agreements





Summary



- **CCP continues to facilitate the development and certification of U.S. industry-based Crew Transportation Systems**
- **Boeing and SpaceX are meeting contractual milestones and maturing their designs**
 - A significant amount of hardware is in development, test, and qualification in preparation for upcoming missions
 - Risks are being identified and important design challenges are being addressed
 - NASA is engaged in meaningful insight
- **Both providers are making tangible progress toward flight tests and crewed missions to the International Space Station**
- **CCP has robust and efficient processes for certification, including addressing waivers and deviations**
 - Progress is being made in the burn down of key certification products with the providers
- **Crew members have been assigned to missions**
- **Inter-agency work continues to enable the commercial spaceflight industry**
- **In preparation for flight, there is significant work ahead**



Boeing CST-100 Starliner



SpaceX Crew Dragon



- NASA has set forth a clear set of principles to guide its ISS transition plan for 2024 and beyond, and submitted a report on ISS transition to congress. The committee looks forward to reviewing the responses from industry to NASA's most recent NASA Research Announcement (NRA) on ISS transition, which are expected in December of 2018.
- The Committee is encouraged to see the level of support from the president and congress for NASA's sustainable approach to human exploration beyond low earth orbit as evidenced by the president's space policy directives, the most recent NASA authorization act, as well as the 2018 and 2019 NASA budgets. It will be exciting for the committee to monitor and review plans for returning humans to cislunar space and to the surface of the moon as they are developed over the next year. **At this meeting the committee saw some preliminary plans for lunar landers. More information is expected after the president's budget is submitted to congress.**
- The committee members support NASA's plans for a lunar orbiting platform that will enable international and commercial partnerships, reusability of hardware to transport crews to and from the lunar surface, reduce risk for lunar exploration crews by providing a safe haven, improve communications with spacecraft on the lunar surface, and provide valuable opportunities for scientific investigations, while expanding the knowledge base in the area of deep space maneuvering and solar electric propulsion required for travel to Mars.
- The approach and flexibility displayed by NASA in its commercial cargo program is resulting in the provision of essential services at a cost lower than previously possible. Where appropriate, other programs such as SLS and Orion should be allowed to take advantage of aspects of the commercial cargo program that enabled success at a lower cost. A similar procurement approach to that used for ISS cargo is planned for future programs such as PPE, the gateway habitation module, and some components of the lunar lander. It would be helpful to fully document and formalize the procurement and management approach that worked well for ISS cargo.
- **Complexity of commercial crew and gateway will result in integration challenges that should be anticipated to minimize problems. Approaches proven on ISS and clearly expressed standards will help to make the integration problem manageable.**



- As the Commercial Crew Program, SLS and Orion finish their development phases and transition toward operations, NASA's approach to program governance may unnecessarily slow the resolution of critical issues as they make their way through the programs and independent technical authorities for final resolution.
- NASA has been working with their Russian partners to maximize the on orbit stay time for Soyuz vehicles which will ensure US crew presence at ISS through January of 2020. If operational availability of commercial crew vehicles for station crew rotation is delayed beyond January, 2020, US crew presence aboard ISS could be lost. The ISS and Commercial Crew programs are continuing to look for ways to keep US crew members aboard ISS, if the first commercial crew flights are delayed.
- Low SLS and Orion Launch rate pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure.
- Shifting priorities may result in the reduction of government funding for the ISS before a viable U.S. commercial follow-on capability is established. This capability is critical to allow NASA continued access to low Earth orbit for research, deep space exploration system testing, and other applications that may arise.
- The current HEOMD organization is working well due to its strong management team and also due to the synergy that comes from having exploration development and operations in the same mission directorate. Efforts to reorganize HEOMD at this time could increase the risk level of NASA's human exploration programs, especially considering the large amount of critical engineering work that must be completed prior to the first launches of the Commercial Crew vehicles, SLS and Orion. **If a reorganization is determined to be the best course for NASA, SLS and Orion are at the point where they should remain part of the HEO organization.**



- Future Special Topics:
 - International Participation in future human exploration
 - ISS after 2024 and ISS commercialization efforts
 - Deep space telescopes and possible servicing missions
 - Planetary Protection
 - Program decision making approach and independent technical authorities
 - Exploration EVA Capability***
 - HEO External Review Summary
 - SLS and Orion activities to increase launch rate
 - Mars Transport Maintenance, Parts Commonality and Redundancy Strategy
 - Lunar Orbital and Surface Operations – Science and Exploration
 - Commercial Participation in future human exploration
 - Communication of NASA's plans for Human Exploration
 - ISS Component Reliability – Predicted vs Actual***

*** Discussed at this meeting – December 2018



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